National Aeronautics and Space Administration

NASA facts

Glory: Refining Understanding of Earth's Energy Budget

A Changing Planet

Over the past century, the average global temperature has increased by 0.7°C (1.3°F). While many lines of evidence show that increasing levels of greenhouse gases are behind the trend, there are other factors that can also impact the climate. Of note, airborne particles called aerosols and small variations in the sun's irradiance can also have a critical impact on the climate.

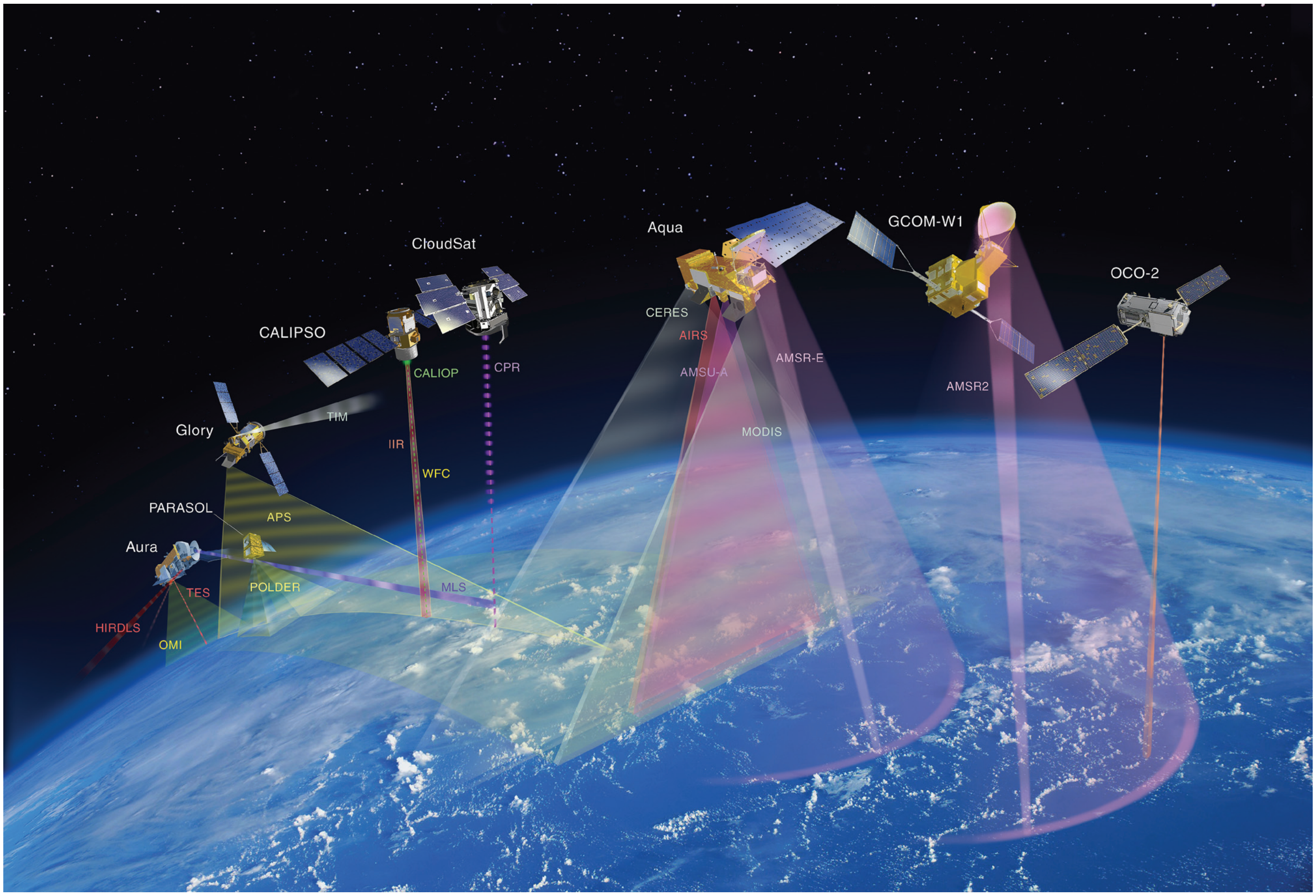
Glory, one of NASA's Earth-observing climate satellites, will extend and improve measurements of both aerosols and the sun's total solar irradiance. In doing so, the mission will help refine scientists' understanding of Earth's energy budget and make it more feasible to accurately predict how climate change will impact different regions of the planet.

Missing Chapters of the Climate Story

Every second, 500 million tons of hydrogen fuse into helium within the sun's core as part of a massive chain of thermonuclear reactions that yield the energy equivalent of billions of exploding hydrogen bombs. This energy eventually makes its way to the sun's surface and radiates outward in the form of light—some of it on a trajectory toward Earth.

Only some of the energy that reaches Earth's upper atmosphere will thread its way through the atmosphere in such a way that it affects climate. Much of it ricochets off the atmosphere, and the rest is temporarily absorbed, only to be radiated back out into space.

An artist's depiction of Glory in orbit. Credit: NASA/Goddard Space Flight Center



A diagram of NASA's A-Train. Credit: NASA/Goddard Space Flight Center

Crucial among the gatekeepers are aerosols, tiny liquid and solid particles suspended in the atmosphere. Certain aerosols reflect radiation away from Earth, while others absorb it readily. Collectively, aerosol particles—which encompass everything from industrial pollution to sea salt to dust—play a key role in influencing Earth's climate.

For climate scientists, aerosols pose a challenge. They are extremely complex, short-lived, and dynamic. As a result, determining the best way to measure their abundance, quantify their behavior, and forecast their impact remains challenging. Nonetheless, both the U.S. Climate Change Science Program and the Intergovernmental Panel on Climate Change have identified aerosol research as a top priority.

The Glory satellite—which contains a sophisticated aerosol monitoring instrument that collects data at 9 different wavelengths from the visible to short-wave infrared spectrum—will help fill the gap. It should offer scientists a much improved understanding of how aerosol particles affect climate.

Glory has another important climate-related objective: to maintain and improve a decades-long record of total solar irradiance (TSI), the amount of solar radiation striking the upper atmosphere each second. Though considered constant in a broad sense, solar radiation actually fluctuates slightly as the sun cycles through periods of more and less intense activity approximately every eleven years.

While scientists have concluded this eleven-year variability isn't substantial enough to cause the warming observed on Earth in recent decades, the sun provides the baseline of Earth's climate over the long term. Accurate records of the sun's irradiance will improve the accuracy of climate models and help scientists tease out the sun's longer cyclical changes that could have a more powerful impact on climate.

Aerosols: Cooling the Planet or Warming It?

Atmospheric aerosols include, but are not limited to, smoke, dust, sand, volcanic ash, sea spray, and smog. Scientists estimate that about 90 percent of aerosols enter the atmosphere through natural processes; the other 10 percent is the result of human activity. Aerosol particles range from a few nanometers—less than the width of the smallest viruses—to several several tens of micrometers—about the diameter of human hair.

Most aerosols tend to cool Earth's surface. Yet, different types of particles have different impacts on temperatures in the lower atmosphere and at Earth's surface. For instance, black carbon—which is a partially combusted carbon produced most often by burning coal, diesel fuel, or biomass—warms the Earth's atmosphere by absorbing sunlight and re-emitting it as infrared radiation that gets trapped by the atmosphere. Black carbon can also coat the surface of ice, making it less reflective and more apt to melt. Overall, some research suggests black carbon is second only to carbon dioxide in its warming impact on Earth.

Other aerosols seem to have the opposite effect. Sulfates, which are produced by volcanic eruptions and the combustion of sulfur-bearing fossil fuels, reflect the sun's radiation back into space. When Mount Pinatubo erupted in the Philippines in 1991, millions of tons of sulfur dioxide spewed into the air, and scientists predicted—and subsequently observed—a dimming of sunlight and a slight cooling of global temperatures.

Most aerosols remain in the atmosphere for just a week or two before natural processes remove them. While airborne, they tend to be remarkably mobile and unpredictable. It's not unusual for particles to waft thousands of kilometers in just a week. Satellites have shown that Saharan dust plumes frequently cross the Atlantic and reach the Caribbean and Amazon basin.

To predict the impact of climate change on human society, scientists need to know precisely how much warming and cooling aerosols produce in different regions of the planet. For this, detailed knowledge of certain aerosol properties—their size, shape, and chemical composition—is required. Since existing satellite instruments only provide partial information about such properties, the climate impact of aerosols remains much less certain in comparison to that of greenhouse gases.

In recent decades, NASA has launched several missions that provide information about aerosols as part of its ongoing Earth and climate observing efforts. The Glory mission will initiate a new sequence of advanced aerosol studies from orbit by flying an innovative instrument, called the Aerosol Polarimetry Sensor (APS), that will sample previously unmeasured characteristics of the light scattered by aerosol particles.

The property of light that APS will measure—its polarization state—will likely reveal new details about aerosol characteristics that should make it possible to distinguish between different aerosol types from space more accurately. Ultimately, data from Glory's APS instrument, in conjunction with ongoing aircraft and satellite measurements and modeling, should provide much needed clarity about how aerosols impact Earth's climate.

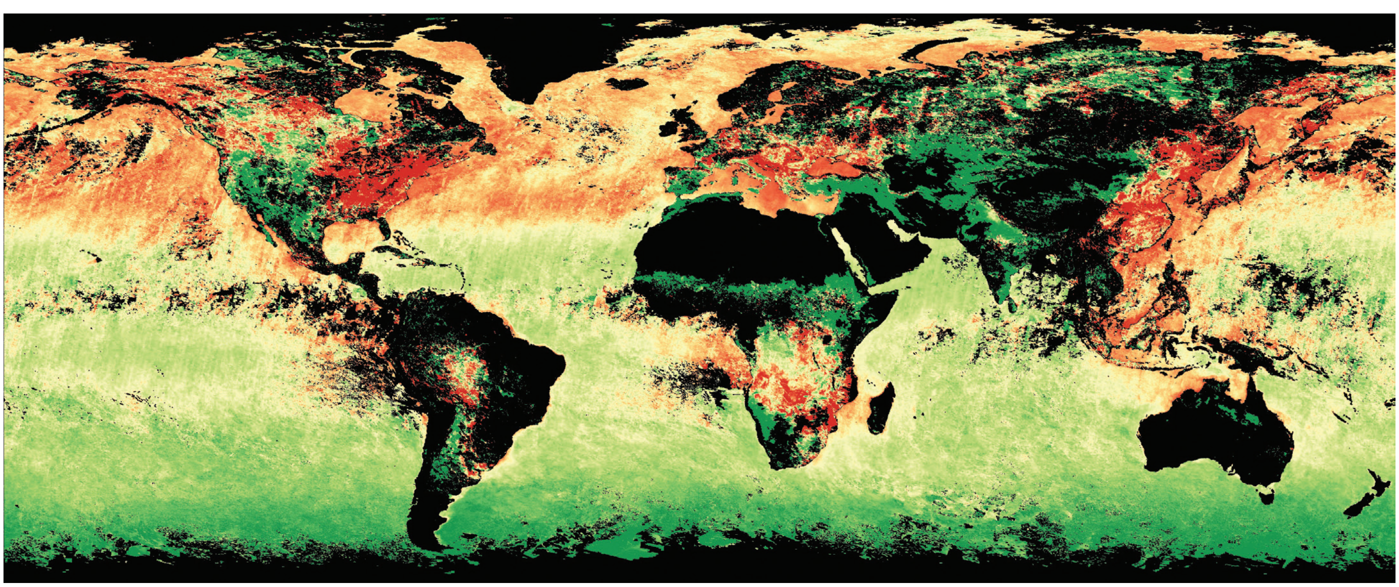
Total Solar Irradiance: The Sun Also Changes

Ground-based measurements of incoming sunlight, or total solar irradiance (TSI), have long suggested that the amount of incoming energy remains nearly constant from year to year. In fact, some researchers erroneously refer to the amount of energy arriving from the sun as the "solar constant".

In reality, scientists have discovered that the output of the sun actually fluctuates slightly as the sun progresses through periods of more and less intense electromagnetic activity on cycle ranging from a few minutes to decades. Since 1978, satellite instruments have allowed solar scientists to make extraordinarily precise TSI measurements to check whether the "solar constant" really is constant.

The instruments have measured with such accuracy that it's been possible to detect tiny variations in TSI that occur within a solar cycle. Periods of intense solar activity—characterized by peaks in sunspots (cool dark blotches on the sun's surface) and faculae (hot bright spots adjacent to sunspots)—cause the sun's irradiance to increase slightly. Overall, solar irradi-

A map showing aerosol particle radius from August 2009. Larger aerosols (shown in green) tend to have natural sources: Salt aerosols are visible over the oceans, and dust is visible over the Saharan desert. Finer-grained urban aerosols are concentrated over the eastern United States and eastern Asia, particularly China. The fine aerosols in subtropical Africa are related to agricultural fires. Credit: NASA/Goddard Space Flight Center



ance varies by approximately 0.1 percent—or about 2 watts per square meter between the most and least active parts of a solar cycle.

Scientists who study the links between solar activity and climate are confident that such small variations cannot explain the intensity and speed of warming seen on Earth during the last century. The 0.1 percent shift simply isn't enough to have a strong influence, and there's no convincing evidence that suggest solar irradiance has trended upward enough over the last century to affect climate significantly.

However, it's possible—probable, in fact, that sun experiences sizable shifts in TSI over much longer time scales that could impact climate. For example, a 70-year period called the Maunder Minimum, which featured exceptionally low numbers of sunspots, is thought to be connected to a period of especially low solar irradiance that helped drive Europe's Little Ice Age.

Glory carries an instrument called the Total Irradiance Monitor (TIM) that will help maintain the long-term satellite record of the sun's irradiance. The instrument is an improvement on a similar TIM instrument launched in 2003 as part the Solar Radiation and Climate Experiment (SORCE) mission. The Glory TIM is designed to offer the most accurate TSI measurements ever collected, which should be about 3 times more accurate than previous instruments.

In the past, subtle differences in the design of successive TSI instruments have caused noticeable offsets in the data. In most cases, scientists have been able to correct for such discrepancies by comparing data from overlapping missions. However, in a few cases, gaps of time between instruments injected a degree of uncertainty into the TSI record. If the new Glory TIM instrument proves as accurate as planned, it will reduce the overall uncertainty and the current reliance on overlapping missions.

The TIM instrument contains four identical radiometers capable of monitoring the sun during the daylight portion of each orbit. It will collect data in 50-second intervals that will also be averaged to provide daily values. The instrument is mounted on a platform that allows mission controllers to aim it toward the sun independently of the orientation of the spacecraft.

Logistics

The Glory satellite, which has a mass of approximately 525 kilograms (1,157 pounds), will launch on a four-stage, solid fuel rocket from Vandenberg Air Force Base in California. At 1.9 meters (6.2 feet) by 1.4 meters (4.6 feet), Glory isn't much taller than most people or wider than an oil barrel.

Following separation from the launch vehicle, mission operators will conduct verification tests of the satellite and science instruments for a 30-day period prior to the start of normal science data collection, which will continue for a period of at least three years. Glory will fly in a low-Earth polar orbit of 705 km (438 miles)—about the distance between Boston and Washington, D.C.

Glory will take its place among a series of Earth-observing satellites, dubbed the Afternoon Constellation or A-Train, which orbit the planet in a cluster at the same altitude and inclination. The close proximity of satellites on the A-Train allows researchers to easily compare data from complementary science instruments flying on adjacent satellites.

Management

Orbital Sciences Corporation is responsible for operating the spacecraft from its Mission Operations Center in Dulles, Virginia

The Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado will command the TIM instrument, monitor its performance, and generate its science data products.

NASA's Goddard Institute for Space Studies (GISS) in New York City will schedule APS instrument activities, monitor instrument performance, and generate aerosol and cloud data products.

Data from both instruments will be archived and distributed by the Goddard Earth Sciences Data and Information Services Center (GES DISC) at NASA's Goddard Space Flight Center (GSFC) in Greenbelt, Maryland.

Web sites

For complete, up-to-date information about the Glory mission, please visit:
http://nasa.gov/glory
http://glory.gsfc.nasa.gov
http://glory.giss.nasa.gov

National Aeronautics and Space Administration

Goddard Space Flight Center
Street Address
Greenbelt, MD 20771

www.nasa.gov

FS-2010-09-109-GSFC